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(71) Applicants
Daimler-Benz Aktiengesellschaft, (FR Germany), Stuttgart-Unterturkheim, Federal Republic of Germany.

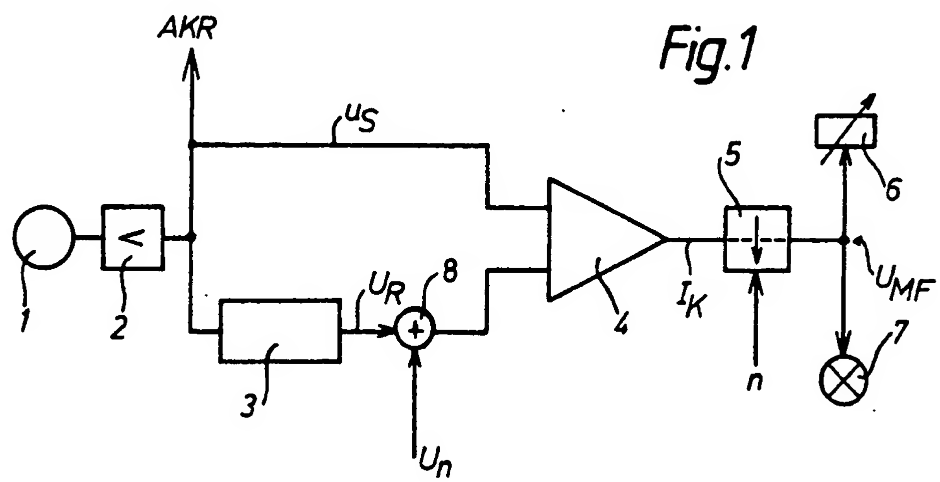
(72) Inventors
Ingo Dudeck,
Jurgen Schenk,

(74) Agent and/or Address for Service
Jensen and Son,
8 Fulwood Place,
High Holborn,
London WC1V 6HG.

(54) Detecting the failure of electrical sensors

(57) A device for detecting the failure of a sensor 1 which is installed on a machine having at least one rotating part, a reference signal U_R being obtained rectifying, smoothing and modifying the level of the output signal U_s of the sensor 1, and this reference signal U_R being compared, in a comparator 4, with the output signal U_s, and the normal output pulses from the comparator 4 being employed to trigger a retriggerable one-shot multivibrator circuit 5. The absence of the output signal U_s initiates an alarm 7 and/or an adjustment of certain machine sub-systems 6. The arrangement can be employed for monitoring knock sensors in internal combustion engines.

Fig.1



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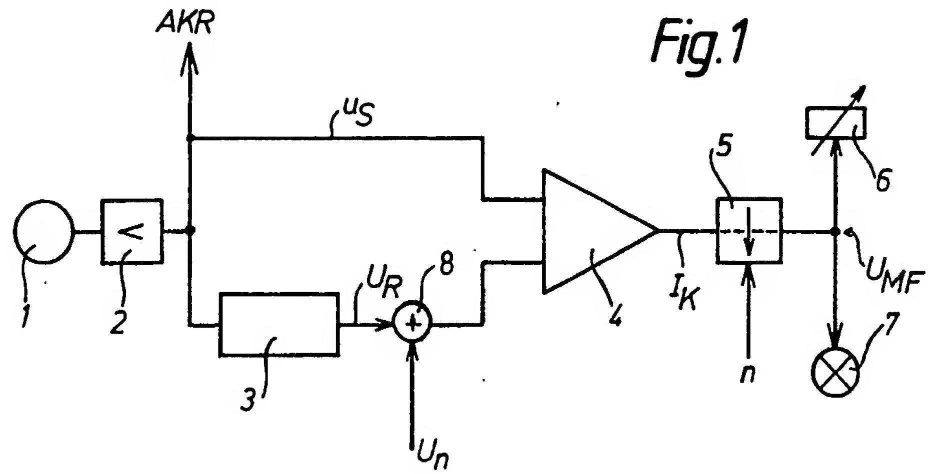
AKR
u_S
U_R
8
5
6
U_{MF}
I_K
1
2
3
4
7
n
U_n

Fig.1

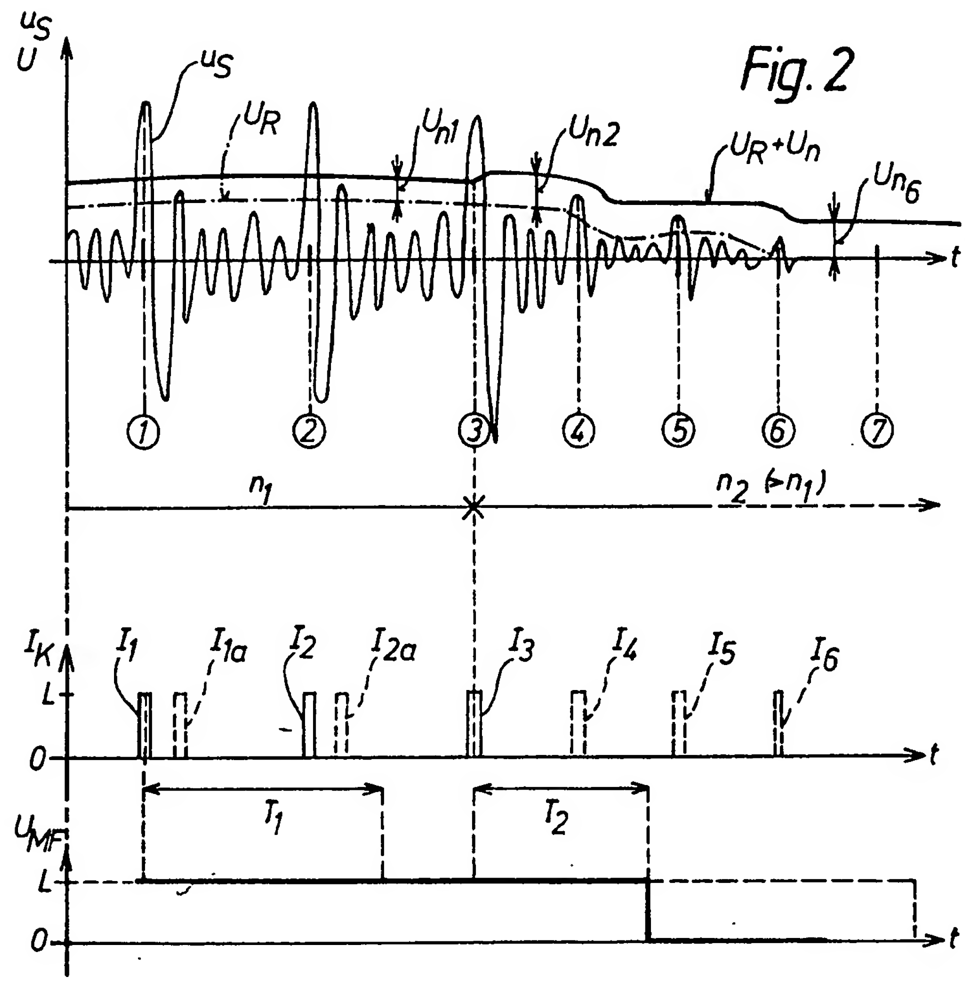
u_S
U
U_R
U_{n1}
U_{n2}
U_R+U_n
U_{n6}
t
1
2
3
4
5
6
7
n_1
n_2 (>n_1)
I_K
I_1
I_{1a}
I_2
I_{2a}
I_3
I_4
I_5
I_6
L
0
T_1
T_2
U_{MF}

Fig. 2

SPECIFICATION

A device for detecting the failure of a sensor

The invention relates to a device for detecting the failure of a sensor which is installed on a machine fitted with a rotatable component of components such as the failure of a knock sensor which is installed on an internal combustion engine, the output signal from this sensor being converted, in a reference circuit, to a rectified and smoothed reference signal which is compared, in a comparator, with a further quantity, a signal appearing at the output terminal of the comparator for as long as this further quantity exceeds the reference signal.

In many machines in which sensors are employed for regulating or controlling specific functions, the correct functioning of these sensors is of particular importance, since a failure of the sensor can lead to significant operational breakdowns or to the destruction of these machines. Thus, for example, the failure of a knock sensor which is installed on an internal combustion engine and the output signal of which is used for the automatic follow-up adjustment of th curve characterising the ignition timing, to conform with variations in the knock limit, can lead to rapid destruction of the internal combustion engine.

One device for detecting the failure of a sensor can be found in German Offenlegungsschrift 2,942,250. In the case of this device, tests are performed during test phases which lie between the combustion processes to determine whether the amplitude of the knock threshold lies within defined limits. A device of this type is insufficiently sensitive to react quickly enough in the event of a slow failure of the sensor.

The object of the invention is accordingly to provide a device which, in the event of a fault, is capable of reacting in a considerably more sensitive manner to a failure of the sensor, and which can emit an alarm signal as quickly as possible and/or adjust the machine which is to be monitored, so that consequential damage is minimised.

According to the invention there is provided a device for detecting the failure of a sensor which is installed on a machine fitted with at least one rotatable component the output signal from the sensor being converted, in a reference circuit, to a rectified and smoothed reference signal U_R which is compared, in a comparator, with the output signal (U_s) from the sensor, the reference signal (U_R) being diminished or amplified to the extent that it is continually exceeded by the peak values, appearing at regular time intervals, of the output signal (U_s) from the sensor, a signal appearing at the output terminal of the comparator for as long as said peak values of the output signal (U_s) from the sensor exceed the reference signal, a one-shot multivibrator being provided, which is adapted to be re-triggered by the output signal (I_K) from the comparator and which has a delay time exceeding the time intervals of the output signal (U_s) from the sensor, a control device and/or an alarm device being series connected, after the one shot multi-vibrator, and, in operation, emitting a control signal and/or an alarm signal if the output signal (U_{MF}) from the one-shot multivibrator vanishes.

According to the invention, a rectified and smoothed reference signal is formed from the sensor output signal, this signal exhibiting a curve shape which is a function of the load on the rotating machine parts and of the speed at which they are rotating, and in the case of internal combustion engines is, for example, a function of the variation of the compression pressure in a cylinder, of the structure-borne noise or of the ignition voltage, and this reference signal is diminished to the extent that, in each period, it is exceeded at least once by the peak value of the sensor output signal - the term "period" to be understood, both here and in the text which follows, as the mean time interval between the peak values of the sensor output signal at the rotation speed *m* at the time in question. These exceedance-events are detected in the comparator, the output signal from which is used for triggering a retriggeralbe one-shot multivibrator, so that when the sensor is functioning correctly, the multivibrator is always triggered and emits a continuous signal. If the sensor fails, the triggering pulses are also absent and, after expiry of the flip-flop delay, the multivibrator ceases to output a signal. The zero signal at the output terminal of the multivibrator is regarded as a failure signal and is used for emitting an alarm and/or an adjustment of the machine which is to be monitored.

Enhanced reliability with regard to faulty operation can be obtained if a speed-dependent signal is added to the reference signal, since this procedure permits not only the total failure to be detected, but also permits the detection of a marked reduction in the sensitivity of the sensor, which usually precedes a total failure.

Greater reliability with regard to faulty operation and more rapid detection of a failure can likewise be achieved if the delay time of the one-shot multivibrator which, if constant, must be longer than the period time at the slowest rotation speed, can likewise be varied as a function of the speed of the rotating machine part, so that it is, at all times, only somewhat longer than the period time at the speed prevailing at the moment in question, or of the function which is derived from this speed.

An embodiment of the invention will now be described by way of example with reference to the drawing in which:-

Figure 1 shows a schematic circuit diagram of the device, and

Figure 2 shows the variation, as a function of time, of the individual signals.

In Figure 1, the knock sensor 1 which is to be monitored is diagrammatically represented as a circuit, this sensor forming part of a so-called anti-knock control system, AKR, for an internal combustion engine. It can, for example, be a piezoelectric acceleration sensor of the type employed in control systems of this nature. Its output signal exhibits an alternating form which varies, in a periodic manner, between large-amplitude pulses and small-amplitude pulses, as a result of the fact that the machine parts are rotating or as a result of

the functions which are derived from these parts (in the case of internal combustion engines, the time-dependent variation of either the combustion pressure or the ignition voltage). After any amplification and filtering which may be necessary, performed in a circuit which is diagrammatically indicated as Box 2, this signal reaches, as the sensor output signal U_s, the anti-knock control system (AKR) which is not represented in the Figure, but is indicated by an arrow.

This sensor output signal U_s is supplied to a reference circuit 3, in which a rectified and smoothed reference signal U_R is derived and is diminished or amplified to the extent that it is continually exceeded by the peak values, appearing at regular time intervals, of the normal, that is to say undisturbed, output signal U_s from the sensor. A rotation speed signal U_n which is a function of the speed at which the machine component is rotating is added, in the form of a direct-current voltage, to the reference signal UR appearing at the output terminal of the reference circuit 3, this addition operation being performed in an analog adding circuit 8. The sum signal $U_R + U_n$ is supplied to one of the input terminals of a comparator 4, the sensor output signal U_s being applied to its other input terminal. The comparator emits an output pulse I_K when the sensor output signal U_s rises above the sum signal $U_R + U_N$. These output pulses I_K are employed to trigger a retriggerable one-shot multivibrator 5, the duration of the output pulses from this multivibrator likewise being variable, as a function of the speed at which the machine part is rotating, and amounting, for example, to 1.5 times the period of the sensor output signal U_s. By this means, it is ensured that each of the pulses, which occur at least once per period, triggers the one-shot multivibrator, provided that its output pulse, triggered by the previous triggering pulse, it still present. As a result, if the sensor is intact, a constant digital output signal U_{MF} is produced, which is employed for triggering an alarm device 7 and a control device 6, for example for adjusting the ignition timing. The alarm is triggered whenever the output signal U_{MF} disappears.

The time-dependent variation of the individual signals is shown, in Figure 2, over a certain time. The sensor output signal U_s is represented as an alternating voltage signal with varying amplitudes, from which it is easy to recognise the "periodic variation" of the signal. The beginnings of the successive periods are respectively marked by the circled numbers 1 to 7. The periods 1 and 2 are assigned to a defined rotation speed n_1, while the following shorter periods are assigned to a rotation speed n_2 which is higher by a factor of approximately 1.5. In the periods 1 to 3 the sensor signal can be said to be "normal", while in the periods 4 and 5 they are reduced, due to reduced senitivity of the sensor, as a sign that a failure is beginning and, from period 6 onwards, they are no longer present, due to the fact that the sensor has failed.

The reference signal U_R, represented by a dash-dotted line, is formed from the sensor output signal U_s, for example by peak value rectification, and is diminished to the extent that it is exceeded by at least one or two peaks of the sensor output signal. If this is the case, the comparator 4 emits output pulses I_K, which are represented in a second diagram drawn on a matching time scale. In the case of all the output pulses I_1 to I_6, drawn with continuous lines and broken lines, the index figures being assigned to the correspondingly numbered period, the sensor output signal U_s exceeds the reference signal U_R. This also holds for the periods 4 and 5, during which the reference signal is, together with the reference signal is used as a threshold value, reduced sensor sensitivity is not detected as a fault. For this reason, a direct-current voltage which is a function of the rotation speed is added, as a speed signal U_n, to the reference signal U_R. In the upper diagram of Figure 2, the result $U_R + U_n$, is represented as a continuous line, the value U_{n1} being assigned to the rotation speed n_1 and the value U_{n2} being assigned to the rotation speed n_2. As a result, on the one hand, the duplicated pulses I_{1a} and I_{2a} are discarded, since they do not rise above the new threshold value $U_R + U_n$. For the same reason, the pulses I_4 and I_5 are discarded. I_6 is discarded because even very small peaks in the sensor output signal which still rise above the reference signal, which is tending to zero, now no longer reach the value U_{n6}.

The difference can clearly be seen in the output signal U_{MF} from the one-shot multivibrator, this signal being plotted, against time, in the third diagram. The delay time T of the one-shot multivibrator, which is a function of the rotation speed, a duration of 1.5 times the period corresponding to the current rotation speed having been mentioned as an example, is marked T_1 for the speed n_1 and T_2 for the speed n_2, and, triggered by the pulses I_1 and I_3 respectively, is plotted in each case as an arrow in the direction of the time axis.

In the case in which the reference signal U_R serves as the threshold value, the output signal U_{MF} does not terminate until the delay time of the one-shot multivibrator, triggered by the pulse I_6, has expired, in the seventh period, the reduction in the sensitivity of the sensor, occurring as a result of its becoming faulty, having been undetected, since only its complete failure is detected. This signal is represented by a broken line.

In the other case, in which the rotation speed signal U_n was added to the reference signal, the pulse I_3, at the output terminal of the comparator 4, is the last before the sensitivity of the sensor decreases to an extent such that the threshold value $U_R + U_n$ can no longer be exceeded. The output signal U_{MF}, represented by the continuous line, terminates as soon as the delay time T_2, triggered by I_3, expires, in the fourth period, so that, in this case, it is already possible to initiate the alarm and/or the adjustment three periods earlier.

The failure detection device which has been described can be used in conjunction with all sensors which emit a "periodic signal" and is not, therefore, restricted to knock sensors for internal combustion engines.

CLAIMS

1. A device for detecting the failure of a sensor which is installed on a machine fitted with at least one rotatable component the output signal from the sensor being converted, in a reference circuit, to a rectified and smoothed reference signal U_R which is compared, in a comparator, with the output signal (U_s) from the sensor, the reference signal (U_R) being diminished or amplified to the extent that it is continually exceeded by the peak values, appearing at regular time intervals of the output signal (U_s) from the sensor, a signal appearing at the output terminal of the comparator for as long as said peak values of the output signal (U_s) from the sensor exceed the reference signal, a one-shot multivibrator being provided, which is adapted to be retriggered by the output signal (I_K) from the comparator and which has a delay time exceeding the time intervals of the output signal (U_s) from the sensor, a control device and/or an alarm device being series connected, after the one shot multi-vibrator, and, in operation, emitting a control signal and/or an alarm signal if the output signal (U_{MF}) from the one-shot multivibrator vanishes.

2. A device according to Claim 1, wherein an adding circuit is provided, in which, in operation, a speed signal (U_n) is added to the reference signal (U_R), this speed signal (U_n) being a function of the rotational speed of the rotating machine component.

3. A device according to Claim 1 or 2, wherein the duration of the output pulse from the one-shot multivibrator is variable as a function of the rotational speed of the rotating machine component.

4. A device according to Claim 1, 2 or 3 wherein said sensor comprises a knock sensor installed in an internal combustion engine.

5. A device for detecting the failure of a sensor which is installed in a machine having at least one rotatable component, substantially as described herein with reference to, and as illustrated in the accompanying drawing.

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